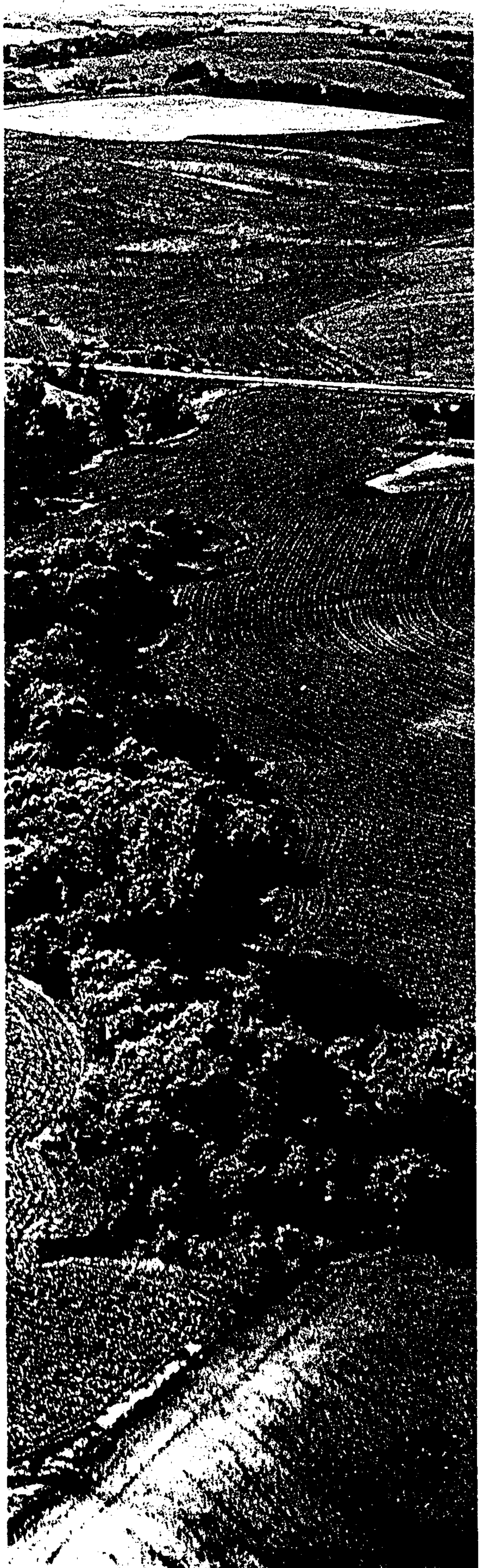

Water table management on a watershed scale

By R. O. Evans, J. E. Parsons, K. Stone, and W. B. Wells

CROPS are grown on nearly 20 million acres of poorly drained soils along the Atlantic Coast and Gulf States (*21*). In many of these states, cropland drainage has been one of the most important components of land management. Many of these artificially drained soils are adjacent to environmentally sensitive and ecologically important estuarine waters.

Agricultural runoff has been implicated in the degradation of water quality and the potential destruction of many saline primary nursery areas (*14, 20*). Agricultural production is important to the region, but it has become obvious that future agricultural practices must be designed and managed with water quality in mind.

Excessive soil water is a major concern on poorly drained soils. In humid regions, artificial drainage is necessary to facilitate seedbed preparation and planting (spring trafficability criteria) and to minimize yield reductions from anaerobiosis. In general, drainage systems have been designed to lower the water table sufficiently to satisfy extreme drainage conditions 80 percent of the time.

For most crops, there is an optimum planting date (*22*). Yields fall when planting is delayed past that date. The most extreme conditions, that is, the wettest periods, occur during the early spring in most years. During this period, evaporation is low enough that excess water must be removed by the drainage system to lower the water table to allow planting by the optimum date.

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While wetness is the major concern, weather conditions vary such that crops periodically suffer from drought stresses that also can reduce yields substantially in some years. Thus, intensive drainage systems that were designed and are necessary to provide trafficability during extreme wet periods tend to remove more water than necessary during drier periods, leading to temporary overdrainage.

These problems and concerns are resulting in a transition from conventional drainage to water table management systems that provide drainage during wet periods but also eliminate overdrainage by using control structures to manage the water level in the drainage outlet (*2, 24*). Drainage control also may reduce the transport of agricultural nutrients to sensitive coastal waters (*1, 7, 8, 10, 11, 12*). Stream water-level control has the potential to retain rainfall on site, in some cases providing a supplemental water source for sprinkler irrigation (*4, 5, 16, 17*). On flat landscapes, these systems may also facilitate subirrigation (*3, 17, 23, 24*).

There are two approaches to water table management: watershed or hydrologic unit systems and on-farm systems. Most water table management installations thus far have occurred at the farm level, although a few watershed-scale projects have occurred (*2, 3, 4, 16*). For example, in North Carolina, water control structures have been installed on more than 150,000 acres, but only 7,500 acres of that total are represented by watershed-scale systems (*8*). There is growing interest in multiuser systems representative of watershed-scale projects, however.

Watershed-scale systems

Channel water-level control has good potential in poorly drained areas where drainage outlet improvements have been made in the past. In the southeastern United States, this includes many of the areas drained under Public Law 566. In many of these project areas, overdrainage does occur where deep channels have been installed in sandy soils having low water-holding capacity and high hydraulic conductivity (2). Shallower channels could be used to minimize the overdrainage, but then channel maintenance, flood control, and drainage during wet periods could pose problems. The best solution in many of these areas is channel water-level control. Primary site factors that influence the feasibility of channel water-level control or watershed-scale water table management include topography, the existing drainage network, soil permeability, and site evaulation.

Topography. Water table management will be most effective on relatively flat soils. While there is no absolute limit, average slopes of less than 0.1 percent are the most practical. As the slope increases, the number and cost of control structures necessary to maintain a uniform water level usually become economically prohibitive. At greater slopes, field water-level control may be a more practical solution. For example, each water control structure on large watersheds (several thousand acres) may cost $20,000 or more because each structure must be sized to carry the 10-year recurrence flow from the upstream watershed. On a 0.1 percent slope, a structure would be required every 1,500 to 3,000 feet of channel length. The difference in drainage area between adjacent structures likely would be several hundred acres. Yet each control structure on the main channel would be sized to carry the flow of the entire upstream watershed, which may include several thousand acres. Under such conditions, it may be more economical to control field ditches with smaller structures, typically costing less than $2,000, rather than controlling the main channel with large structures.

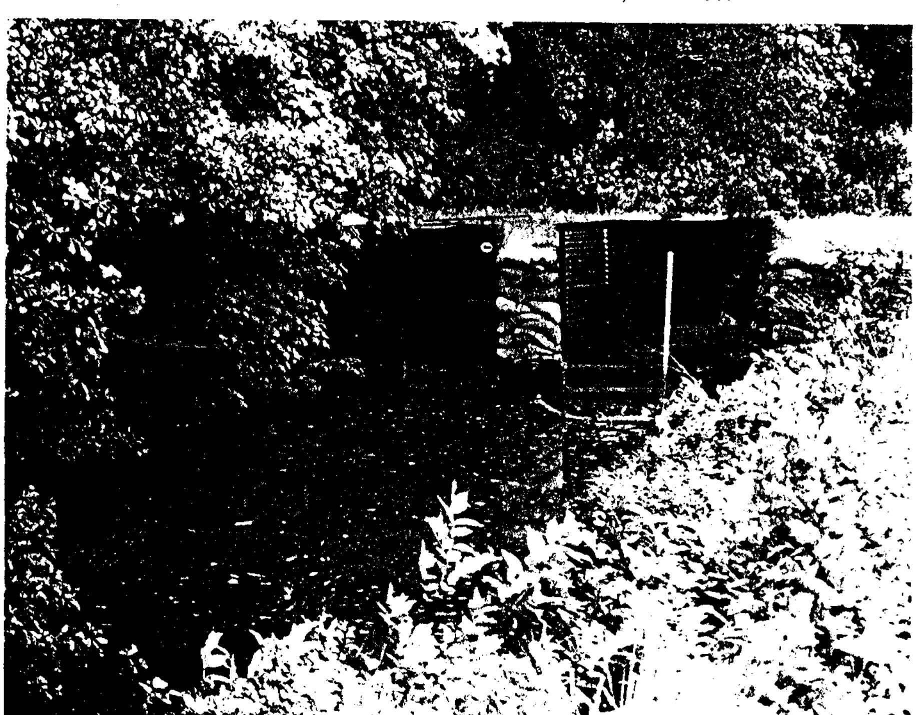
Existing drainage network. The existing drainage channel network is also important in assessing the potential for channel water-level control. Deeper channels enable larger hydraulic gradients toward the drainage ditches. This is important where channel storage will be used to supply water for sprinkler irrigation. Even in large channels, the actual storage capacity of the channel is low relative to crop water requirements on the surrounding land area. Large sprinkler irrigation systems that require 1,000 gallons per minute or more will exhaust the channel storage within a few hours. Thus, to provide sufficient water for large sprinkler systems, recharge to the main channel must be rapid. This requires relatively large gradients between the water level in the channel and the water table level in the surrounding fields and/or large lateral hydraulic conductivity (permeability) in the soils surrounding the main channel.

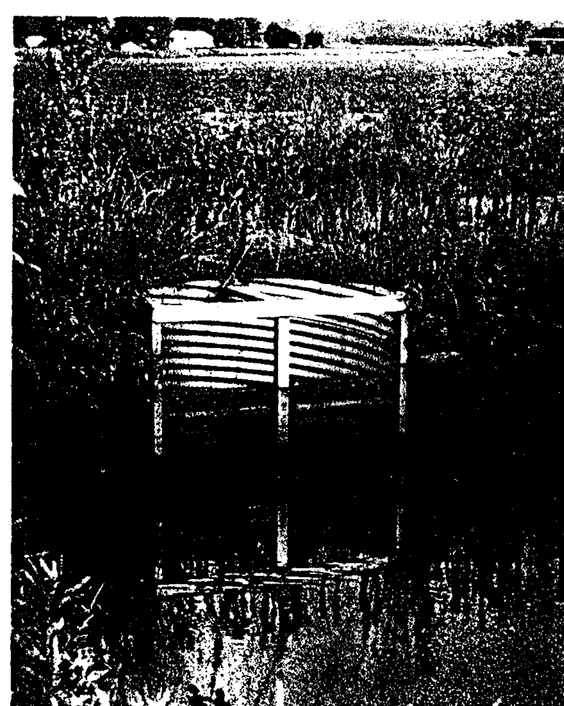
Soil permeability. The permeability of the saturated zones determines the extent of im-

Top, right: Field-scale, flash-board riser-type water control structure installed in lateral field ditch in Washington County, North Carolina. Drainage area influenced (controlled) by structure is 32 acres. Length of weir is two feet.

Bottom, right: Farm-scale, flash-board riser-type v· .er control structure installed on main drainage ditch in Chowan County, North Carolina. Upstream drainage area controlled by structure is 250 acres. Length of weir is five feet. Note, for the condition shown, the water level in the ditch would have to rise about one foot before any outflow would occur.

Below: Watershed-scale, flash-board riser-type water control structure(s) installed in main channel in Perquimans County, North Carolina. Upstream watershed drainage area controlled by structure is about 2,500 acres. Effective length of the weir, that is, the combined width of the two structures, is 12 feet.





pact of the channel water-level control on the adjacent land areas. Soils within the watershed must have similar subsoil permeabilities to provide uniform drainage when the main channel is controlled. Fields with clayey subsoils will drain slower than fields with sandy subsoils. Thus, soil heterogeneities among fields within the same watershed must be considered before implementing control of the main channel. The response of dissimilar fields within the same watershed usually will be more acceptable with field-level control, in which each field can be managed independently.

Subsoil permeability also will affect the rate of recharge to the main channel to provide water for sprinkler irrigation. Recharge from clayey subsoils will be slow and may not be adequate to support large-scale sprinkler irrigation. Sandy subsoils with high permeabilities more effectively recharge the main channel.

Site evaluation. While most artificially drained soils will respond to water table control, the net benefits of watershed-scale channel control will vary according to topography and hydraulic parameters of the watershed. Detailed soil and site evaluations are necessary to evaluate the potential of the watershed for channel water-level control. Once accurate soil and site data are obtained, the potential benefits of these projects can be evaluated using computer simulation models, such as WATRCOM (*18, 19*).

Watershed-scale benefits

Water conservation. With suitable soil and site conditions, as discussed above, channel control can conserve soil water and reduce the demands on groundwater or off-site water supplies to accommodate irrigation.

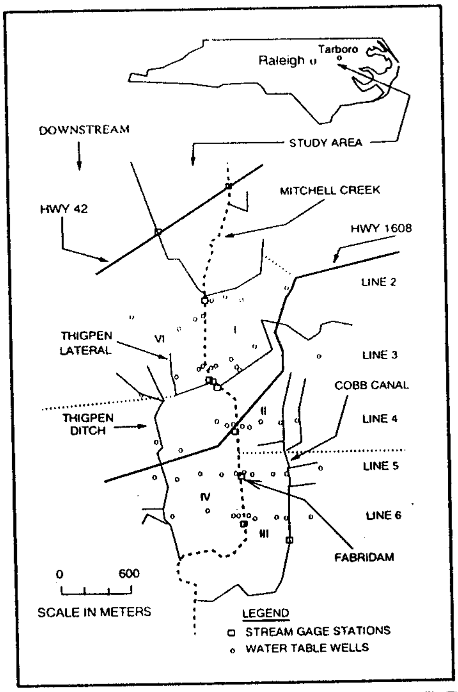
Doty and associates reported the water conservation potential of a watershed-scale research and demonstration project near Tarboro, North Carolina (*6*). The area encompassed about 2,000 acres of poorly drained soils with coarse sandy subsoils five feet below the soil surface. An inflatable dam structure, called a Fabridam, was installed on the Mitchell Creek watershed of the Conetoe Creek Drainage District in 1982. The structure was controlled to provide drainage in spring and fall. During the growing season, the structure was set to provide additional water supplies and raise the field water tables for crop water use.

At the start of the project in 1980, two center pivots and two volume gun irrigation systems used the channel water for supply. By the end of the project evaluation and demonstration period in 1985, there were eight center-pivot systems, four volume gun systems, and one controlled drainage-subirrigation system.

Without channel control to provide a water source, irrigation growth in the project area would have been limited because water availability from other sources, primarily groundwater, would not economically support the area irrigated. At the end of the project evaluation period, management authority for the fabridam structure was returned to the local landowners and Conetoe Creek Drainage District. The fabridam structure has continued to be managed to provide a water source from Mitchell Creek to supply the irrigation systems. Portions of Mitchell Creek were dredged in 1989, about 10 years after the start of the project, to remove accumulated sediments and re-establish the storage capacity of the main channel.

Soil types and land uses within the watershed influence the water source potential of watershed-scale channel control. The fabridam project in North Carolina was successful for two reasons. First, a large portion of the watershed was upstream from the project area. Thus, outflow from this area provided part of the water source for the project area. Second, the sandy subsoils provided rapid recharge to the channel from the water table aquifer. Collectively, these sources provided sufficient water to irrigate nearly half the acreage within the project area. The collapsible fabridam provided the opportunity to recycle this water through irrigation. Yet it allowed flood flows to pass without damaging crops.

In many drainage district watersheds, the water table aquifer could provide an adequate water source for sprinkler irrigation,



Schematic layout of Mitchell Creek watershed study in Edgecombe County, North Carolina. Influence of fabridam control structure extended upstream to about highway NC 42. (16).

Inflatable dam-type water control structure, fabridam, installed in Mitchell Creek. When managed (raised) as shown, the fabridam influences channel water level 1.8 miles upstream of structure. Structure is fully designed to automatically lower during flood conditions, resuming preset elevation once flood conditions have ceased. Upstream watershed drainage area contributing to streamflow is about 12,000 acres. Effective top length of weir when fully inflated is about 40 feet. Design and operational specifications were reported by Doty and associates (4).

provided the channel is deep enough to dewater the aquifer and the soils are sufficiently permeable to provide rapid recharge. Many channels are not deep enough to dewater the water table aquifer to provide all of the water that may be needed by crops. The average drainable porosity of many coastal plain soils is about 0.07 to 0.10 inch per inch that the water table is lowered. Therefore, for typical channel depths of six feet, the maximum potential water yield obtained by lowering the water table from two feet to six feet is 4 to 5.5 inches, about half the average seasonal irrigation requirements (10 inches/year) in the humid Southeast. Upstream water will supplement this amount, provided the upstream land areas also are not being cropped and need irrigation.

Parsons and associates, in a study using the WATRCOM simulation model (*18*), estimated that the size of the upstream area would have to be four times the irrigated area to provide all the water for irrigation during an average growing season, that is, 50 percent of the time. Larger upstream areas would be needed to provide all the water for irrigation during years drier than average. About 40 to 50 percent of the area of a typical southeastern watershed is cropped; the remainder is in forest. Water can be stored in the forested areas and released when needed to irrigate crops. During dry periods, however, the trees also use some of this water, and outflow from the forested areas would not be sufficient to supply irrigation requirements of all cropped land within many watersheds.

Channel control will facilitate more efficient use of water within the watershed, thus reducing the demands on other water supplies. But, channel control will not provide sufficient water to satisfy all irrigation requirements in all years. Parsons and associates estimated that the irrigation supply on the Mitchell Creek watershed in North Carolina could be increased two to four times with channel control compared to no control, depending on seasonal rainfall (*18*). For the period simulated, they estimated that the average storage capacity of the channel and surrounding water table aquifer could provide an irrigation source for droughts up to 17 days. Droughts exceeding 17 days occur about 25 percent of the time (one year in four) in the area. Thus, channel water-level control would provide the irrigation requirements in about three out of four years. Without channel water-level control, the same area could be irrigated for only four days. Droughts exceeding four days occur at least once during each growing season in four out of five years. Thus, without channel water-level control, irrigation requirements could be met only one out of five years.

Number and type of irrigation systems, irrigated area, irrigation water pumped, and average annual irrigation application, Mitchell Creek water table management project, 1980-1985 (6)

Year*	Number of Systems†			Irrigation Water from Mitchell Creek‡§ (acre-feet)	Area Irrigated (acres)	Average Application§# (inches)
	CP	VG	CDSI			
1980	2	2	-	78	195	4.8
1981	2	3	-	152	292	6.3
1982	5	3	-	93	350	3.2
1983	6	4	1	286	519	6.9
1984	6	3	1	5	704	0.8
1985	8	4	1	212	808	3.2

*Rainfall during the growing season (April-August) was well below normal in 1980 and 1983; somewhat below normal in 1981, 1982, and 1985; and near normal in 1984.
†CP = center pivot, VG = volume gun, CDSI = controlled drainage/subirrigation.
‡Volume pumped from Mitchell Creek, as measured with flow meters.
§Water applied in the 20-acre controlled drainage-subirrigation system was not measured.
#Total volume pumped divided by the irrigated area.

Summary of corn yields at the Mitchell Creek project, 1981-1985 (*16*)

Year	Corn Yields (bushels/acre)			
	No Stream Control		Stream Water Control	
	Nonirrigated	Irrigated	Nonirrigated	Irrigated
1981	103	170	-	-
1982	110	132	132	164
1983	51	125	86	158
1984	118	152	117	166
1985	110	141	157	176
Mean	98	144	123	166

As the net benefits of channel control become apparent to producers within a watershed, most of the producers eventually want to withdraw water from the main channel. This was the case in the Conetoe Creek project, as evidenced by the growing number of irrigators within the project area as the project progressed. This increased use diminishes flow to downstream users. Where more than 25 percent of the watershed is cropped, such use likely would consume all channel flow at some point during the growing season (*18*). Thus, while channel control improves water use efficiency within a watershed, all producers within a watershed should not expect channel control to provide all of their irrigation water requirements.

Effects on yields. Channel control may have positive effects on crop yields. In the Conetoe Creek project, surface-applied irrigation increased corn yields compared to nonirrigated corn yields, in each year. All of the irrigation water was supplied from the main channel, with additional recharge to the channel from the water table aquifer. Corn yields increased in most years in both irrigated and nonirrigated fields because of the direct effect of water-level control in the main channel. The direct benefit of channel control was greatest near the channel where overdrainage of the coarse-textured sandy soils had occurred for more than 30 years since the channelization of Mitchell Creek. The direct effect of channel control decreased as the distance from the channel increased (*2*).

Topography is one of the main factors influencing the direct yield benefits of channel control. Where the watershed slope is relatively flat, the water table can be maintained within the optimum range with relatively few control structures. As the slope increases, water table depths will vary more unless more structures are installed. As discussed, when slopes exceed about 0.1 percent, field-scale control likely will provide more uniform water table depths than watershed-scale control on the main channel. This was the case at the Conetoe Creek project. While the control structure influenced field water table elevations one-half mile from the main channel, the land surface elevation increased away from the channel. As a result, the depth from the land surface to the water table increased during dry periods as the distance from the channel increased. Channel control had little effect on yields more than 700 feet from the main channel, even on these coarse-textured sandy soils.

Parsons and Skaggs used the WATRCOM model to predict the influence of channel control on yields for several control scenarios: no channel control, lateral channel control, lateral and main channel control, and lateral and main channel control with inflow from upstream areas within the watershed (*17*). Simulations were made for five years, including wet, dry, and normal years. They predicted that corn yields would increase by controlling the channels compared with uncontrolled channels. Control on the main channel would increase yields in the area near the channel but would have little effect on yields more than 300 to 700 feet from the channel. During dry periods, water storage and upstream inflows would not be sufficient to prevent the channel water levels from declining below the control level. These simulation results were consistent with trends observed in the Conetoe Creek project.

Simulated relative corn yields for four levels of stream water-level control (*17*)

K (feet/day) and Year*	*Growing† Season Rainfall (inches)*	*Relative Yield‡ (%)* *No Control*	*Lateral Ditches Controlled*	*Main and Lateral Ditches Controlled*	*Main and Lateral Ditch Control with Upstream Inflow*
0.25					
1982	11.3	71	75	76	77
1983	8.4	38	46	46	55
1984	19.3	70	82	83	86
1985	15.0	77	82	82	85
1986	6.8	32	38	38	47
Mean	12.1	57.6	64.6	65	70
5.0					
1982	11.3	68	80	82	87
1983	8.4	32	43	45	51
1984	19.3	57	78	83	93
1985	15.0	74	81	81	81
1986	6.8	28	36	36	40
Mean	12.1	51.8	63.6	65.4	70.4

*K is lateral hydraulic conductivity. Values shown represent the ranges of values observed in the Mitchell Creek project area.
†Seasonal rainfall during the critical moisture period for corn (May, June, and July). Normal rainfall for the same period is 13 inches and potential evapotranspiration is 17.5 inches.
‡Relative yield is the yield for a given year or scenario, expressed as a percentage of potential yield, where potential yield is the yield that would occur in the absence of any soil-water related stresses.

In-stream water quality effects of stream water-level control on Mitchell Creek (*6*)

Water Quality Parameter	*Location* *At Fabridam** *Control (April-Sept.)*	*No Control (Oct.-March)*	*1.8 Miles Upstream†* *Control (April-Sept.)*	*No Control (Oct.-March)*
pH	6.7	6.5	6.6	6.4
Conductivity (lmho/cm)	154.0	132.0	154.0	125.0
Nitrate-nitrogen (ppm)	2.2	3.6	3.3	3.8
Total Kjeldahl nitrogen (ppm)	0.60	0.62	0.59	0.54
Total nitrogen (ppm)	2.8	4.2	3.9	4.3
Total phosphorus (ppm)	0.057	0.046	0.048	0.032

*Control period was April through September each year from 1982 to 1985.
†The 1.8 miles upstream from fabridam was upstream from zone of influence of control structure.

Effects on drainage water quality. Unchannelized Coastal Plain streams are usually shallow, with broad, flat floodplains covered by hardwood forests. During high flow periods, these streams frequently overflow their banks and inundate the surrounding floodplain areas. Because of the gentle stream slope, water velocities are low in the floodplains even during large floods (*15*). To reduce flooding and provide main drainage outlets for agricultural production and other activities, many streams have been channelized under PL-566 flood control projects. Channelization reduces the flood duration in the surrounding areas by increasing stream capacity and peak discharge rates.

Increased transport of sediment and fertilizer nutrients and loss of riparian vegetation often follow channelization. Kuenzler and associates (*15*) reported a five- to tenfold increase in nitrate-nitrogen, a two-fold increase in sediment, and a three-fold increase in attached phosphorus because of channelization. Similar results have been reported for field-scale drainage activities (*13*).

In field-scale systems, drainage control can reduce nitrogen and phosphorus transport 30 to 50 percent compared with uncontrolled drainage systems (*1, 7, 10, 11, 12, 25, 26*). Watershed-scale drainage control also may reduce outflow and nitrogen and phosphorus transport. However, the magnitude of the reduction is not as well documented as in field-scale systems. Doty and associates observed that stream water-level control on Mitchell Creek reduced instream nitrate-nitrogen concentrations on an annual basis by about 25 percent (*6*). Stream control occurred about six months during each year (April-September), with no control from October through March. During periods of no stream water-level control, nitrate-nitrogen concentrations near the fabridam were about the same as concentrations 1.8 miles upstream, beyond the zone of influence of the control structure. During control periods, nitrate-nitrogen concentrations near the control structure were about 50 percent less than 1.8 miles upstream. Further study is needed to better document the effects of channel control on drainage water quality, particularly with respect to sediment, phosphorus, and pesticides.

Problems and barriers

Channel water-level control has good potential in areas where drainage outlet improvements have been made. Channel control in these watersheds potentially can improve water use efficiency within the watershed, provide direct yield benefits in some cases, and improve drainage water quality of watershed outflows, at least in terms of nitrate transport. However, watershed-scale projects, such as the Mitchell Creek project, have been slow to develop. Several obstacles must be overcome to implement watershed-scale projects.

Land classification and assessment. Improvements on most of the main channels in watershed projects in the Southeast were performed as drainage district improvements. The primary purpose of PL-566 channel improvement projects was to provide flood protection to landowners in the watershed. A land classification scheme normally was used to determine benefits and subsequent assessments to individual landowners based on the proximity of their land to and potential benefits resulting from the drainage improvements. Two potential watershed channel control projects in North Carolina have failed to develop because attempts were made to apply the same land classification system to the channel control projects as was applied for drainage and flood protection.

Today, most watershed land has multiple uses. While all of the uses likely would benefit from drainage improvements to provide flood protection, not all would receive the same relative benefit from channel control. As a result, homeowners in particular have been unwilling to accept assessments to fund channel control-type improvements for which they see no benefits. Obviously, the land classification statute for drainage improvements will not be adequate or equitable for unilateral application to channel control projects. Statutes in the land classification system used by drainage districts need to be reviewed and revised to equitably distribute the cost of channel control projects. Until this is done, watershed-scale channel control projects will continue to be slow to develop and likely limited to watersheds where mulitiple uses of the land do not exist.

Another problem facing channel control projects is the question of which landowners have rights to withdraw and use water in the main channel. Rights to withdraw and use flowing surface water in most eastern states are provided only to landowners "riparian" or adjacent to the stream, provided they are making reasonable use of the water. Many watersheds have nonriparian landowners who under riparian rules would not have rights to surface water in the main channel. This raises a question about the source of the water in the main channel. As discussed, a significant portion of the withdrawable water in Mitchell Creek was provided by recharge from the water table aquifer, that is, the groundwater. This recharge could be provided by both riparian and nonriparian land. In most eastern states, overlying landowners have rights to withdraw and use groundwater, provided they are making reasonable use of the land. It is not clear which of these water rights statutes would prevail or if either is adequate to protect landowners' water rights resulting from channel control-type projects.

Management decisions. Soils, topography, and crops vary throughout most watersheds. Water table levels generally need to be lower to provide trafficability than to provide adequate soil water requirements for a growing crop. A corn producer may desire a water table depth of less than two feet during the corn tasseling stage, while an adjacent farmer may desire the water table depth to be more than three feet to facilitate harvesting wheat and planting soybeans. Who decides what elevation to control the stream water level and who decides when to raise or lower this level during unusually wet or dry periods?

Legal precedence on these questions has not been established. Existing drainage districts have the authority to sponsor water table management projects, that is, install water control structures on main channels. But individuals within the watershed do not have such authority. Water rights associated with the project likely belong to the individual landowners.[1] Water rights likely would be associated with management decisions about the control level because no control provides little or no water. Thus, management decisions probably would be the responsibility of all landowners within the project. This would require agreement among individuals.

In many states, PL-566 projects require a watershed work plan that must be reviewed by the state soil and water conservation commission. To approve a project, those commissions must conclude that the construction and operation of the project will not appreciably diminish the flow of water to downstream users during critical periods, that is, it will not deprive downstream riparian landowners of their rights to also withdraw and use part of the streamflow.[2] During dry periods, channel control with stream withdrawals to supply water for sprinkler irrigation systems may consume all streamflow, eliminating or sharply reducing downstream discharge (*18*). As a result, a commission might find that such would be the case for most projects and not allow development of the project. Even if the project is approved, existing riparian regulations would require lowering of the control level to provide some flow to downstream users. Precedence has not been established to provide project managers guidance on how much water must be allowed to pass the control structure and how much can be withdrawn within the project area. Landowners within the project area should be aware that riparian rights of downstream users may preempt their use of some of the streamflow. Thus, if conflicts arise, the stream likely will not provide a reliable water source to supply all irrigation requirements within the project area.

The future

Channel water table control can improve water use efficiency within a watershed; reduce demands on other water sources to facilitate irrigation; improve crop yields; and reduce the transport of fertilizer nutrients, in particular nitrogen, to sensitive receiving surface waters. The magnitude of the benefits associated with stream water-level control vary among watersheds and from year to year within a given watershed. The success of watershed-scale projects will be influenced by soils, crops, and topography within the watershed; the percentage of the watershed area cropped; hydraulic properties of the watershed; seasonal rainfall; and management strategies.

Most of the poorly drained soils in the Coastal Plain and Tidewater regions of the Atlantic and Gulf States would respond to water table management. Most drainage improvement and flood prevention projects authorized and constructed under PL-566 would respond to watershed-scale projects. Water table management on a farm-unit basis is popular in some states, but watershed-scale projects have been slow to develop.

The technical feasibility of water table management on both a farm-unit basis and watershed scale is fairly well documented. There still remains a need, particularly for watershed-scale systems, to improve and fine tune management strategies to optimize the net benefits of water table management. This need will become more acute as more field-scale systems are expanded to include entire watersheds. In some areas, field-scale projects already are developed to the extent that some landowners would like to expand to watershed-scale projects.

At this time, institutional problems pre-

[1]Heath, Jr., M.S. 1986. "Some Preliminary Thoughts About Water Rights Issues and Related Legal Issues Associated with Water Table Management Projects." Paper presented at a water table management seminar, North Carolina State University, Raleigh.

[2]Ibid.

sent barriers to developing these watershed-scale projects. Until water rights and institutional problems and concerns associated with watershed-scale projects are addressed and clarified, such projects likely will continue to develop slowly. Authority provided to drainage districts to develop PL-566 drainage and flood prevention projects does not appear adequate to address watershed-scale water table management problems that are arising.

Surface water rights and laws in most of the eastern Unitred States address an individual's rights to use water. From an agricultural perspective, this is primarily associated with an individual's right to withdraw water for irrigating crops, which implies that the purpose is increased production. Likewise, PL-566 rules and regulations address drainage and flood prevention, again from an agricultural standpoint, for the primary purpose of increasing production. These laws have been in effect for several decades and in some cases centuries. During most of this time, the primary concern was, in fact, to increase production.

With the recently increased awareness and need to improve water and environmental quality, there clearly are contradictions in existing water rights laws that were developed under a philosophy of increased production. The rights of individuals to implement projects, such as watershed-scale water management, with the added benefit of improving water quality must be addressed. Laws need to be reviewed and, where necessary, revised to reflect the developing philosophy of more efficient production with improved water quality. This may involve restructuring and expanding sponsoring organizations, such as drainage districts, into water table management districts.

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